DOCUMENT RESUME

ED 421 686 CS 013 252

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TITLE Learning Information System Effects on Reading, Language Arts, Math, Science, and Social Studies.

INSTITUTION Institute for Academic Excellence, Inc. Madison, WI.
PUB DATE 1997-00-00
NOTE 19p.; Accelerated Reader is a registered trademark.
AVAILABLE FROM Advantage Learning Systems, Inc., P.O. Box 8036, Wisconsin Rapids, WI 54495-8036 (free to educators).
PUB TYPE Reports - Research (143)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Comparative Analysis; Computer Assisted Instruction; Elementary Education; *Language Arts; *Mathematics Instruction; *Reading Achievement; *Reading Instruction; Reading Programs; Reading Research; *Science Instruction; *Social Studies
IDENTIFIERS *Accelerated Reader Program; Tennessee

ABSTRACT

Scores for five subjects (Reading, Language Arts, Mathematics, Science, and Social Studies in grades 2 through 8) from the Tennessee Comprehensive Assessment Program were analyzed for several hundred Tennessee grade schools. Schools which owned the Accelerated Reader learning information system (a computer program which allows teachers to monitor and manage student literature-based reading) were compared with schools that had not purchased AR. Schools that owned AR outperformed others in all grades and subjects. (Contains five figures and five tables of data; an appendix contains a brief introduction to the Accelerated Reader.) (Author/RS)

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Learning Information System Effects

on Reading, Language Arts, Math, Science, and Social Studies

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An Institute for Academic Excellence Monograph

Learning Information System Effects on Reading, Language Arts, Math, Science, and Social Studies

by Terrance Paul, Scott Swanson, Wenyuan Zhang, and Lance Hehenberger

Abstract

Scores for five subjects (Reading, Language Arts, Mathematics, Science, and Social Studies) from the Tennessee Comprehensive Assessment Program were analyzed for several hundred Tennessee grade schools. Schools which owned the Accelerated Reader® were compared with schools that had not purchased AR. Schools that owned AR outperformed others in all grades and subjects.

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Introduction

The purpose of this study was to examine the relationship between student achievement scores and school ownership of the Accelerated Reader learning information system. To this end, we obtained statewide standardized test scores from the Tennessee Value-Added Assessment System and analyzed them on a school-by-school, grade-by-grade basis, with ownership of the Accelerated Reader as the principal independent variable.

Learning Information Systems

Learning Information Systems (LIS) are computer programs that bring various curricular record-keeping and analysis functions together into a manageable framework.[1] The Accelerated Reader® (AR) is a task-level LIS that allows teachers to monitor and manage student literature-based (as opposed to textbook) reading. It provides teachers with timely data on how much each student is reading and at what level. It also incorporates testing to assure that students are reading with understanding. AR is produced by Advantage Learning Systems, Inc. (ALS), the parent company of the Institute for Academic Excellence. For more details, see Appendix A.

Previous research by the Institute for Academic Excellence has shown that schoolchildren in the United States spend very little of their school day engaged in reading practice.[2] The Theory of Reading Practice, as originally defined by Terrance Paul in *Patterns of Reading Practice*, argued that growth in reading ability depends on the quantity of such practice. Since then, the Institute has refined the theory to incorporate not only the amount of total reading, but also the difficulty of the reading material. The Accelerated Reader enables teachers to track student progress in both reading quantity and reading level. Coupled with various motivational techniques, AR helps teachers increase useful reading practice. Such practice should, according to the theory, lead to higher scores on reading tests.

Earlier studies have also shown that greater amounts of reading practice correlate with higher scores in other subjects, such as math, science, and social studies. One hypothesis to explain this correlation is that reading contributes to growth in higher-order cognitive skills, which leads to better performance in all subject areas. A second hypothesis is that if students are better able to read their textbooks, classroom instruction is more efficient and effective. A third hypothesis is that better readers are simply better test-takers. Probably each of these factors accounts for some portion of the cross-curricu-

lar effect of improved reading; it is not the purpose of this study to further explore that issue.

TVAAS

The Tennessee Value-Added Assessment System (TVAAS) is a project that gathers standardized test scores from the Tennessee Comprehensive Assessment Program (TCAP) and analyzes them using statistical techniques that filter out the effects of factors external to the immediate school environment.[3] TVAAS scores are reported at the school level for each grade and subject. The intent is that communities can use the scores to evaluate the effectiveness of their local schools and to call for changes, if appropriate.

To protect the privacy of teachers and students, TVAAS scores at the classroom level are not made public. However, such scores are made available to teachers, administrators, and school boards. Here, the intent is to identify curricular and instructional weaknesses. Because release of this data is strictly regulated, we were not able to use classroom- or student-level data for our analyses.

The five subjects tested are Reading, Language Arts, Mathematics, Science, and Social Studies. Students are tested in grades 2 through 8. We obtained TVAAS scores for the 1995-1996 school year from the TVAAS web site.[4] The TVAAS web site provides mean scale scores and mean gains, as well as standard error of measurement for both.

It is critical to understand that these scores have been statistically adjusted using a mixed-model method that corrects for various external factors. In particular, the scale scores have been adjusted to account for transient students, or for students simply having missed a testing cycle. The gain scores have been analyzed longitudinally, using each student's performance in previous years (including performance at other schools) as a control. This analysis allows the gains to be adjusted in such a way as to remove socioeconomic and other factors, permitting direct, meaningful comparison of schools.

Using customer purchase data from Advantage Learning Systems, we classified each school in the TVAAS database as: An AR school if it purchased the Accelerated Reader prior to September 1995; a Non-AR school if it had not purchased the Accelerated Reader as of June 1997; or a Transition school if it purchased the Accelerated Reader at any time after August 1995. This report focuses on the AR schools and Non-AR schools, with a brief look at the Transition schools.

Analyses

We compared average mean scale scores and average mean gains for all schools in each of five subjects and six grade levels (grades 3 through 8). That is, TVAAS reports an adjusted mean scale score and an adjusted mean gain for each combination of grade and subject ("grade-subject pair") in each school. We calculated, for each grade-subject pair, the mean of these mean scale scores and mean gains for all AR schools and for all Non-AR schools. Note that we did not calculate a weighted mean based on the number of students in each grade in each school, as TVAAS does not provide this data.

We also calculated the standard deviation of the adjusted mean scale scores and adjusted mean gains for each subject-grade pair for all AR schools and all Non-AR schools. We then determined p-values for the difference between the average adjusted mean scale scores for the AR schools and Non-AR schools, as well as for the average adjusted mean gains.

We also compared the AR and Non-AR distributions of adjusted mean scale scores and adjusted mean gains for each grade-subject pair.

Finally, to address issues of selection bias, we also calculated mean adjusted scale scores for the Transition schools for three subjects: Reading, Language Arts, and Mathematics.

Results

The data are presented in Tables 1 through 5 and illustrated in Figures 1 through 3.

The data strongly suggest a connection between AR ownership and higher achievement on standardized test scores. In every grade-subject pair, the AR schools showed a higher average adjusted mean scale score than the Non-AR schools (Figure 1a). The odds of this occurring by chance would be the same as that of 30 coin tosses all coming up heads: Somewhat less than one in one billion. Analysis of the differences in the means for particular grade-subject pairs showed similar statistical significance, with p-values ranging from a maximum of 0.016 for seventh-grade Social Studies to a low of 1.0×10^{-9} for fourth-grade Language Arts.

Similarly, in 27 of 30 grade-subject pairs, AR schools showed a higher average adjusted mean gain (Figure 1b). The odds of this occurring by chance are approximately four in one million. In general, the statistical significance of the

differences was lower than in the case of the scale scores, but it was still quite high in certain categories. For third-grade reading, for example, we calculated a p-value of 0.019. Interestingly, all three of the cases in which AR did not outperform Non-AR schools were for fifth grade. (See further discussion of grade five in "Conclusions.")

Figure 1a

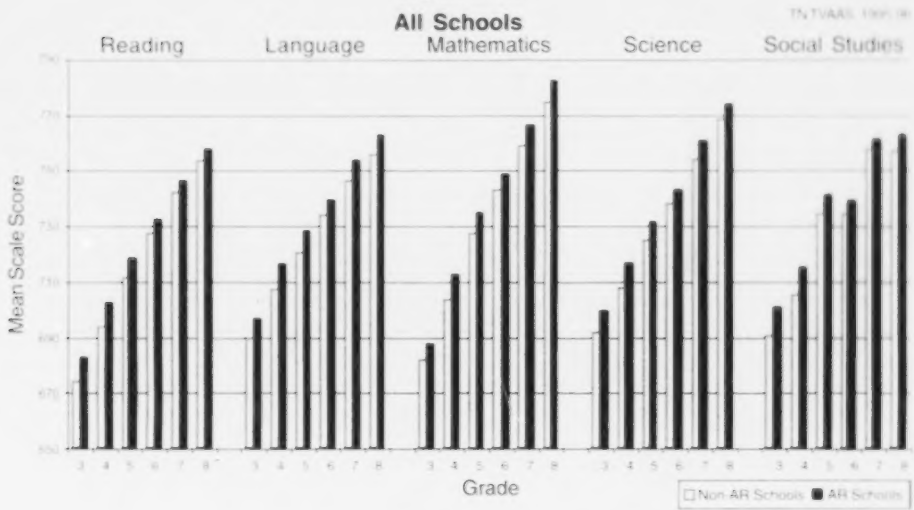
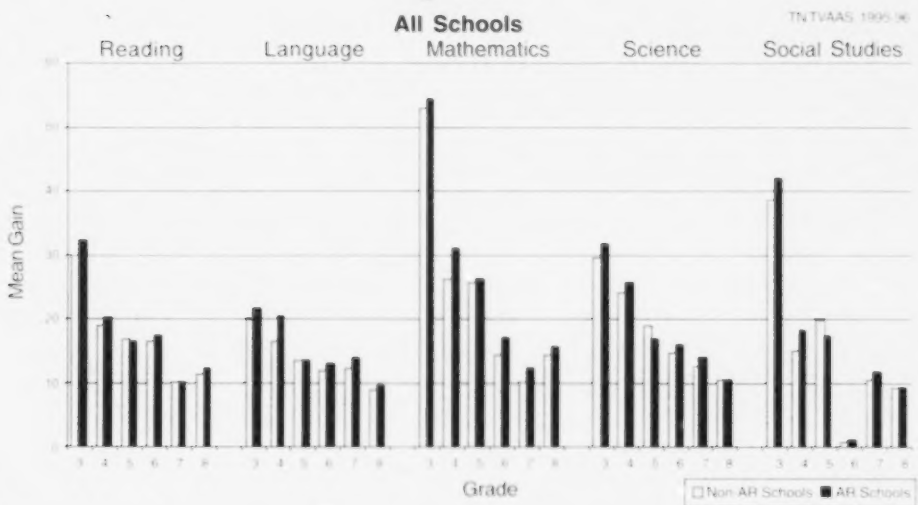


Figure 1b

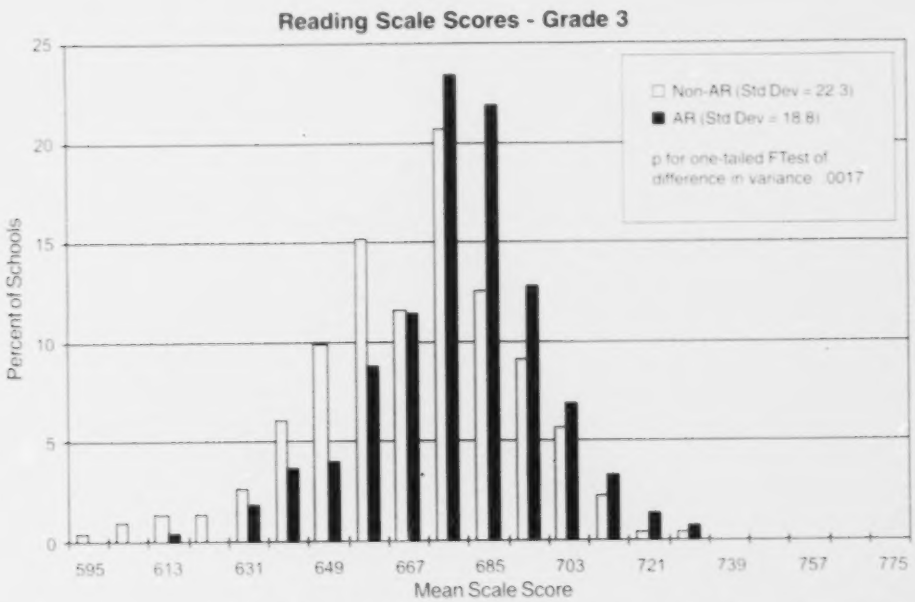


Comparison of average adjusted mean scale scores and average adjusted mean gains for five subjects in AR and Non-AR schools. Note the consistent superior performance of the AR schools. (These data are presented in tabular form in Tables 1 through 5.)

We also observed that the variation among AR schools was lower than that for Non-AR schools. That is, within the group of AR schools, there was much lower variation in the mean adjusted scale scores than within the group of Non-AR schools. This is shown in the standard deviations in Tables 1 through 5. Again, this was true for every grade-subject pair.

When we plotted histograms contrasting the distribution of adjusted mean scale scores for AR and Non-AR schools, we observed that besides a rightward shift of the entire curve (towards higher scores) for AR schools, there was also a narrowing of the curve. This is reflected in the standard deviations calculated in the tables. Moreover, most of the narrowing occurred at the bottom of the distributions; that is, the distributions for Non-AR schools were skewed, with a long tail towards the bottom, while the distributions for AR schools more closely approximate true normal distributions.

Figure 2a



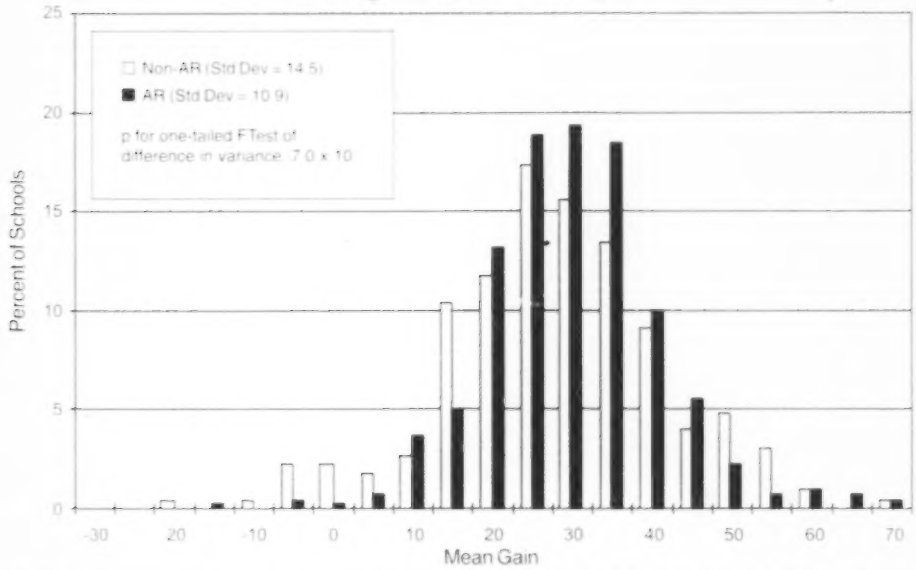
Histogram comparing the distributions of adjusted mean scale scores for AR versus Non-AR schools. The AR schools are shifted rightward relative to the Non-AR schools, and lack the long leftward tail shown by the Non-AR schools.

Taking a particular case for closer examination, consider third-grade reading. AR third grades averaged a mean scale score of 683, while Non-AR third grades averaged 674. (The national norm scale score for third grade is 680.) Although

the difference of 9 scale score points seems small in contrast with the scores themselves, we can obtain an interesting figure of merit by dividing the difference of the average adjusted mean scale scores by the national norm gain for that grade-subject pair. For third-grade reading, 9 scale score points represent approximately 30 percent of the "expected" (i.e., national norm) yearly gain — a very substantial difference.

Figure 2b

Reading Mean Gains - Grade 3

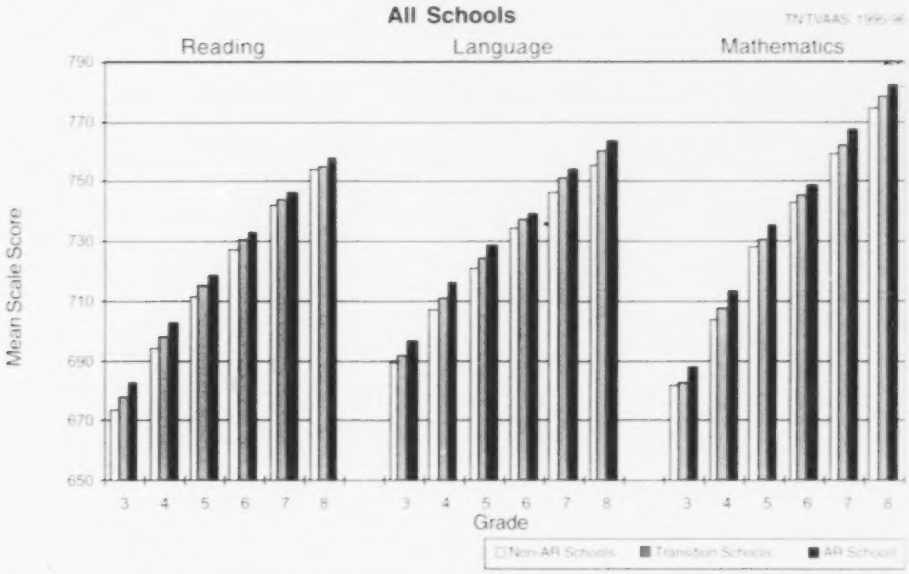


Histogram comparing distributions of adjusted mean gains for AR versus Non-AR schools. The pattern is similar to that of the adjusted mean scale scores.

When we examine the distribution of mean scores for third-grade reading, we see a clear illustration of the difference in score variation (Figure 2a). Far fewer AR schools than Non-AR schools are found in the range below 631. In fact, 9 of 232 Non-AR schools, or 3.9 percent, fell into the 36-point range of 595-630, while only 2 of 457 AR schools, or 0.43 percent, were in that same range. By contrast, note how AR schools are clustered in much larger percentages towards the middle of the distribution. Gains for third-grade reading show a similar pattern (Figure 2b).

When we calculated average adjusted mean scale scores for the Transition schools, we found that for the three subjects studied, the Transition schools' scores fell in the range above the Non-AR schools but below the AR schools, for every grade (Figure 3). This supports the aptness of our label, Transition.

Figure 3



Comparison of average adjusted mean scale scores for AR, Non-AR, and Transition schools. We defined Transition schools as those which have acquired the Accelerated Reader since August 1995. Note that in every grade and subject, the Transition schools averaged higher than the Non-AR schools, but lower than the AR schools.

CONCLUSIONS

On average, Tennessee schools that own the Accelerated Reader show better performance in TVAAS adjusted scale scores than do their peers who do not own the Accelerated Reader. This phenomenon is observed in every subject tested, at every grade level from grade 3 through grade 8. The data indicate very high statistical significance, refuting any suggestion that the effect is due to chance distribution of AR ownership.

It could be argued that AR schools have *a priori* advantages over Non-AR schools, and that these create a selection bias towards the results we observed. For example, we might find that AR schools have more computers than Non-AR schools. However, a previous study by the Institute failed to identify any such factors that could account for the superior performance of AR schools.[5] In the current study, the observation that the Transition schools perform at a level above that of Non-AR schools but below that of AR schools is another obstacle to the argument that some factor other than the Accelerated Reader is responsible for the AR schools' achievement.

One hypothesis is that we are simply measuring an "early-adopters" effect. This is the argument that schools that are among the first to adopt a technique or tool are by definition distinct — in funding, in staffing, in creativity, in energy — from schools that are less willing or able to do so. In the context of this study, one must ask how many schools qualify as early-adopters. About half of Tennessee's elementary schools are represented in the AR sample, with initial purchases of AR as recent as August 1995 or as long ago as 1990. Another fourth are in the Transition sample, having purchased AR between September 1, 1995, and June 30, 1997. These facts do not defeat the early-adopter hypothesis, but they do cast considerable doubt upon it. (See "Further Work" for additional observations.)

One of the most significant findings may be that of the lower variation of adjusted mean scale scores among AR schools than among Non-AR schools. This is in keeping with the goal of providing a satisfactory education to all students in all schools, an objective we view as simple social justice. Apparently, very few AR schools can be considered extremely ineffective; conversely, relatively few of the schools in the lowest echelons are schools that own AR.

Consider again the distribution charts (Figures 2a and 2b) for third-grade reading. Note that on the right side of the charts, the AR and Non-AR schools are not dramatically different, especially for the adjusted gains. The scale scores for AR schools have been "shifted" somewhat to the right, but the general outlines of the AR and Non-AR histograms are similar. However, on the left side, representing the least effective schools in the study, the performance of AR schools is much different from that of Non-AR schools. The AR schools do not show the long leftward "tail" that we see for the Non-AR schools.

This difference in the tails is especially telling in the gains chart. Recall that by using students' own past performance as a control, TVAAS adjusts gains to account for such external factors as socioeconomic status. Thus, it is not arguable that the AR schools simply have *a priori* advantages in their student populations or communities that account for their performance. We ought not to view that long tail among the Non-AR schools as an abstraction. It is a poignant representation of real children being deprived every day of their birthright: A decent, effective, public education.

It is beyond the scope of this study to analyze in any detail the mechanisms by which improved reading ability, regardless of its genesis, might lead to better performance in other academic subjects. Nonetheless, our results strongly suggest that there is indeed such a correlation. If we accept that AR is stimulat-

ing an increase in reading scores, we must also accept that AR is, by some indirect means, stimulating an increase in scores for other subjects.

Of the three hypotheses offered earlier for this effect, probably the least appealing is the third: Students aren't actually learning more math or geography; they're merely doing better on the tests because they can read the questions more quickly and with higher comprehension. However, in adjusting the mean gain scores for each subject, TVAAS explicitly considers the gains in each of the other subjects. That is, by comparing reading and science gains among schools with relatively weak or strong performance in either of those subjects, TVAAS is able to estimate how much difference a certain reading gain would make in science gains at a hypothetical school that offered no science instruction whatsoever. This estimate is then used to adjust the reported gains for each school, helping schools and teachers to more precisely identify where their curricular strengths and weaknesses lie. It has the happy side effect of filtering out a portion of the effect predicted by the third hypothesis.

What do we make of the fact that in terms of mean gain, the one grade in which AR schools do not consistently outperform Non-AR schools is grade five? This is not a surprising result. We must remember that this study says nothing about how (or even whether) schools categorized as AR are using the program. Studies currently underway at the Institute suggest that maintaining a high level of challenge is very important if a student is to benefit from reading practice. We hypothesize that in many of Tennessee's K-5 schools, there are not enough books at higher reading levels to sustain above-average gains through fifth grade. We also know that many Tennessee schools are least effective at educating their most-advanced students — a fact consistent with our hypothesis.[7]

In summary, this study, combined with the Institute's earlier study of the impact of AR in Texas schools, provides increasingly compelling evidence that use of the Accelerated Reader does lead to higher scores across all grades and subjects.

Further Work

Selection bias will always be a concern in a non-controlled study. One way to further address the matter will be to do a longitudinal analysis of scores for a large set of schools over a three-year period: The year prior to purchase of AR, the transition year, and the year after purchase. Because so many Tennessee schools purchased AR during the 1995-1996 school year, we have delayed such a study until the release of 1996-1997 TVAAS data.

As noted above, the question of the "fifth-grade effect" deserves further attention. The Institute has collected extensive AR usage data from almost 300 Tennessee schools that will permit a detailed analysis of this effect. It will also permit us to refine the nature of the current study by categorizing schools according to how much their students are reading and at what level.

Table 1: Reading

	N Schools		Gain						Scale					
			AR		Non-AR				AR		Non-AR			
Grade	AR	Non-AR	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value
3	457	232	32.3	10.9	30.0	14.5	2.25	0.019	682.6	18.8	673.7	22.3	8.91	9.0E-08
4	452	236	20.2	8.4	18.7	10.1	1.51	0.025	702.6	17.0	694.1	20.4	8.52	2.0E-08
5	440	232	16.2	7.7	16.6	8.9	-0.37	0.299	718.6	15.6	711.5	19.8	7.15	9.0E-07
6	294	210	17.4	8.0	16.3	8.8	1.14	0.067	732.5	13.3	727.5	16.6	5.10	1.0E-04
7	210	189	10.0	5.8	10.0	7.4	0.05	0.473	746.3	13.6	742.2	17.5	4.07	5.0E-03
8	208	187	12.2	5.2	11.3	6.5	0.85	0.078	758.1	11.0	753.9	15.8	4.27	1.0E-03

Table 2: Language

	N Schools		Gain						Scale					
			AR		Non-AR				AR		Non-AR			
Grade	AR	Non-AR	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value
3	457	232	21.6	11.2	19.7	14.2	1.84	0.043	696.3	18.5	689.5	20.6	6.80	1.0E-05
4	452	236	20.4	9.0	16.5	10.9	3.93	0.000	716.1	17.8	707.0	19.8	9.15	1.0E-09
5	440	232	13.5	9.1	13.4	10.5	0.13	0.435	728.6	16.0	720.7	19.1	7.94	3.0E-08
6	294	211	12.9	8.0	11.9	9.4	1.04	0.096	739.4	15.0	734.2	18.1	5.19	3.0E-04
7	210	189	13.6	8.3	12.0	9.8	1.58	0.042	754.0	16.0	746.5	19.9	7.53	2.0E-05
8	208	185	9.3	6.4	8.8	8.6	0.53	0.245	763.0	14.8	755.5	17.8	7.52	3.0E-06

Table 3: Mathematics

	N Schools		Gain						Scale					
			AR		Non-AR				AR		Non-AR			
Grade	AR	Non-AR	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value
3	457	232	54.3	16.7	52.9	20.6	1.38	0.189	687.6	19.5	681.6	23.4	6.01	4E-04
4	452	236	30.9	12.6	26.2	14.2	4.72	0.000	712.8	19.0	703.7	21.3	9.11	2E-08
5	440	232	26.0	10.8	25.7	11.5	0.30	0.372	735.0	16.2	727.7	19.4	7.31	5E-07
6	294	211	17.0	10.7	14.1	11.0	2.95	0.001	748.6	16.8	742.7	19.8	5.95	2E-04
7	210	188	12.2	9.9	10.0	12.2	2.17	0.027	766.8	16.4	759.1	21.7	7.78	3E-05
8	208	186	15.6	8.4	14.2	9.1	1.42	0.055	782.4	16.4	774.3	21.1	8.15	1E-05

Table 4: Science

	N Schools		Gain						Scale					
			AR		Non-AR				AR		Non-AR			
Grade	AR	Non-AR	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value
3	457	232	31.7	14.9	29.6	20.1	2.1	0.079	699.1	20.4	691.4	26.0	7.7	4.1E-05
4	452	236	25.6	11.0	24.0	13.8	1.7	0.055	717.0	19.0	708.0	25.1	9.0	6.0E-07
5	440	232	16.7	9.4	18.8	12.4	-2.1	0.013	731.9	16.6	725.3	21.5	6.6	2.0E-05
6	294	211	16.0	10.0	14.7	12.3	1.4	0.092	742.7	15.3	737.8	19.8	4.9	1.3E-03
7	210	188	14.0	10.6	12.6	11.4	1.5	0.094	760.5	14.4	754.4	19.6	6.1	2.2E-04
8	208	187	10.3	8.2	10.2	8.5	0.0	0.482	774.1	13.2	768.3	18.2	5.8	1.6E-04

Table 5: Social Studies

	N Schools		Gain						Scale					
			AR		Non-AR				AR		Non-AR			
Grade	AR	Non-AR	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value	Mean	Std Dev	Mean	Std Dev	Diff Mean	P Value
3	457	232	41.7	15.6	38.5	21.5	3.2	0.021	700.9	23.9	690.5	28.0	10.4	6.8E-07
4	452	236	18.3	11.1	15.0	14.4	3.3	0.001	715.3	18.6	705.6	22.8	9.7	9.1E-09
5	440	232	17.3	10.3	19.7	13.2	-2.5	0.007	741.1	15.5	734.7	20.7	6.3	2.2E-05
6	294	211	0.9	8.3	0.6	10.1	0.2	0.399	739.0	12.8	734.6	16.8	4.4	6.9E-04
7	210	188	11.6	8.0	10.5	11.1	1.1	0.123	761.3	12.6	757.8	19.1	3.5	1.6E-02
8	208	186	9.0	6.4	9.0	6.3	0.0	0.506	762.5	12.6	757.1	18.5	5.5	3.4E-04

APPENDIX A

A Brief Introduction to the Accelerated Reader

The Accelerated Reader is a computerized task-level learning information system for the management of literature-based reading. Its goal is to increase reading practice. This goal dovetails with the findings of *Patterns of Reading Practice*, that the more students read, the better they perform on academic achievement tests in both reading and mathematics.

The program provides tests on more than 13,000 books, each of which has a reading level calculated according to the Flesch-Kincaid readability index. Each book is also assigned a maximum "AR Point Value," derived from its length and reading level according to the following formula:

$$AR\ Points = (10 + Reading\ Level) \times \frac{(\text{Words in Book})}{100{,}000}$$

The procedure for the student is:

1. Select a book from a list of AR-supported titles.
2. Read the book.
3. Go to the computer and take a multiple-choice, objective test about the book.

The test takes the place of book reports and other evaluation tools, assuring the teacher that the student has read the book. The program awards the student AR points equal to the percentage test score times the book's AR Point Value, provided that the student scores at least 60 percent on the test. The combination of test scores and points earned gives teachers a quick, efficient way to track student achievement, enabling timely, effective intervention when indicated. AR provides 21 different reports for teachers, students, and parents.

Notes

1. For a detailed discussion of Learning Information Systems, see: Paul, T. (1996). *Learning Information Systems: Theoretical Foundations.* Madison, WI: The Institute for Academic Excellence. Presented at the National Reading Research Center Conference on Literacy and Technology, October 5, 1996, Atlanta, Georgia.

2. Paul, T. (1992). *1992 National reading study and theory of reading practice.* Madison, WI: The Institute for Academic Excellence. Paul, T. (1993). *National study of literature-based reading: How literature-based reading improves both reading and math.* Madison, WI: The Institute for Academic Excellence. Paul, T. (1996). *Patterns of reading practice.* Madison, WI: The Institute for Academic Excellence.

3. Sanders, W. and S. Horn (1994). "The Tennessee Value-Added Assessment System (TVAAS): Mixed-Model Methodology in Educational Assessment." *Journal of Personnel Evaluation in Education,* 8:299-311.

4. "http://www.state.tn.us/education/rptcrd96/index.html" This site allows you to choose between downloading files or viewing on-line. Viewing on-line provides good background information on the available data. Downloading the files provides more detailed data.

5. Paul, T., D. VanderZee, T. Rue, and S. Swanson (1996). *Impact of the Accelerated Reader Technology-Based Literacy Program on Overall Academic Achievement and School Attendance.* Madison, WI: The Institute for Academic Excellence. Presented at the National Reading Research Center Conference on Literacy and Technology, October 5, 1996, Atlanta, Georgia.

6. William Sanders, Director, University of Tennessee Value-Added Research and Assessment Center, personal communication.

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